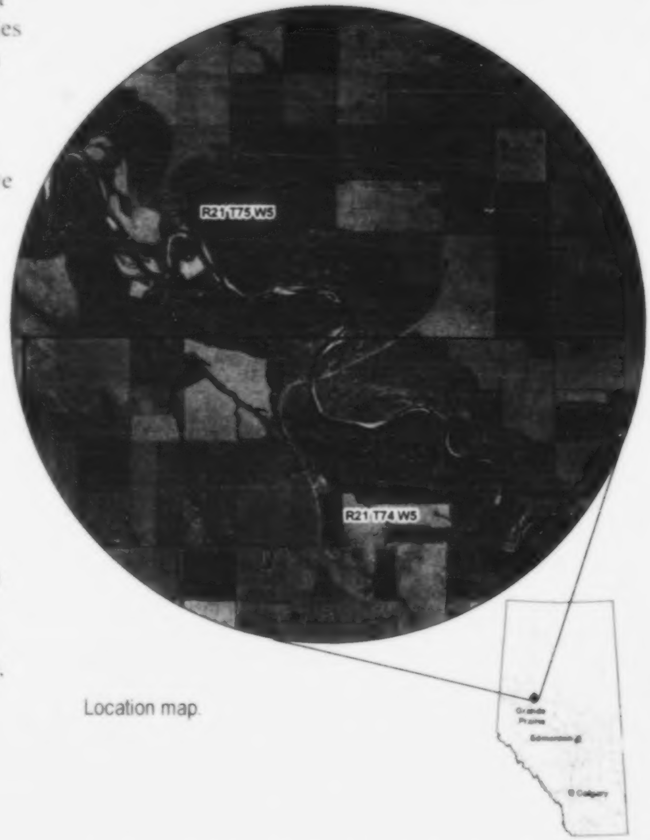
Rock Chips
Summer 2008

Satellite-Based Mapping of Landslide Movements on Little Smoky River

Since 2005, the Geological Hazards Section at AGS has used new remote-sensing technologies to detect and map movements associated with ground hazards in Alberta. One promising technology is Interferometric Synthetic Aperture Radar (InSAR). InSAR emits radar pulses from polar-orbit satellites 800 km above the Earth's surface (Radarsat-1, Envisat and others) to map the distance between the satellite and the ground. As these satellites continuously orbit the Earth, they image the same portion of the Earth at the same angle every 24 to 35 days. By comparing the data received by the satellite between passes, subcentimetre-scale, and in some cases millimetre-scale, changes in the Earth's surface can be detected.

AGS is currently collaborating with the Canadian Centre for Remote Sensing (CCRS) and the Canadian Space Agency to explore the use of InSAR to map ground-hazard movements at three Alberta sites: Frank Slide, Town of Peace River and the Little Smoky landslide. This technology has been highly successful in mapping millimetre-scale deformation in dry, nonvegetated terrain. However, success in northern, vegetated terrain is scarce because ground moisture and vegetative cover negatively affect the data returning to the satellite. One method to overcome these effects is using artificial targets or corner reflectors to amplify the signal returning to the satellite and enable detection of subcentimetre movements.

The Highway 49 crossing of the Little Smoky River was chosen to test the suitability of Corner Reflector InSAR (CR-InSAR) to map ground movements in northern Alberta.



Location map.

The Little Smoky River bridge and approach roads were constructed in 1957. Since then, ongoing valley slope instability has affected the highway and west bridge abutment, causing ongoing, costly maintenance. To characterize these movements, the University of Alberta installed, in the late 1960s, the first slope indicators to be used in Alberta. More recently, detailed studies with instrumentation have been undertaken in the area of a large, ongoing embankment failure on the northeast valley wall. This work provided a viable, long-term solution to mitigate the effects of slope movement on the highway. Stabilizing the slide and moving the

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highway from the area of greatest instability were considered. As these are significant decisions for Alberta Transportation, CR-InSAR is an exciting technology to acquire a wide array of data for the valley walls.

In October 2006, 18 small areas were cleared of vegetation, and corner reflectors were installed by AGS, Alberta Transportation, CCRS and the University of Alberta. The pyramid-shaped reflectors were oriented directly perpendicular to the direction of radar pulses emitted from the Radarsat-1 satellite, which obtains results over the site every 24 days. The reflectors amplify the signal back to the satellite for the heavily vegetated surrounding areas.

As of November 2007, a set of 13 readings was obtained for each reflector and the results processed at the CCRS offices in Ottawa. AGS staff compared these processed results against conventional geotechnical instrumentation on the site (slope inclinometers) and visual interpretations of the complex slope movements on the site.

Installation of corner reflector by staff from AGS and CCRS.

Based on the first year of readings, some very interesting results have been obtained. On the southwest side of the valley, slopes are moving along a trend nearly parallel to the satellite line-of-sight. The overall movement trends agree with readings obtained by conventional geotechnical instruments and provide confidence in the technique to remotely monitor such motion.

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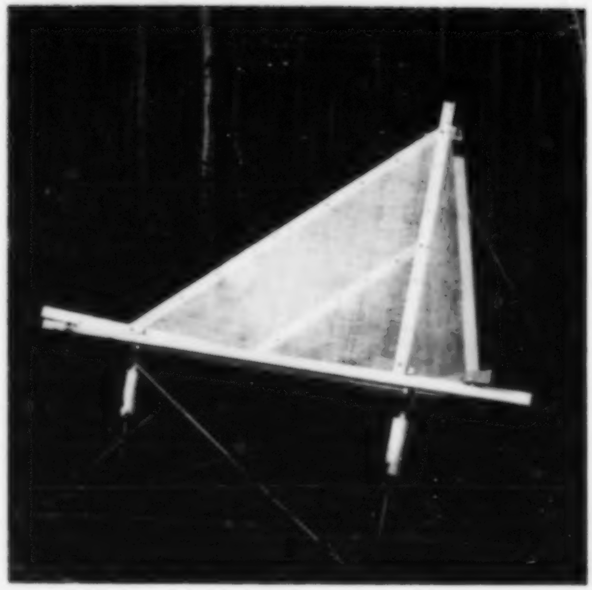
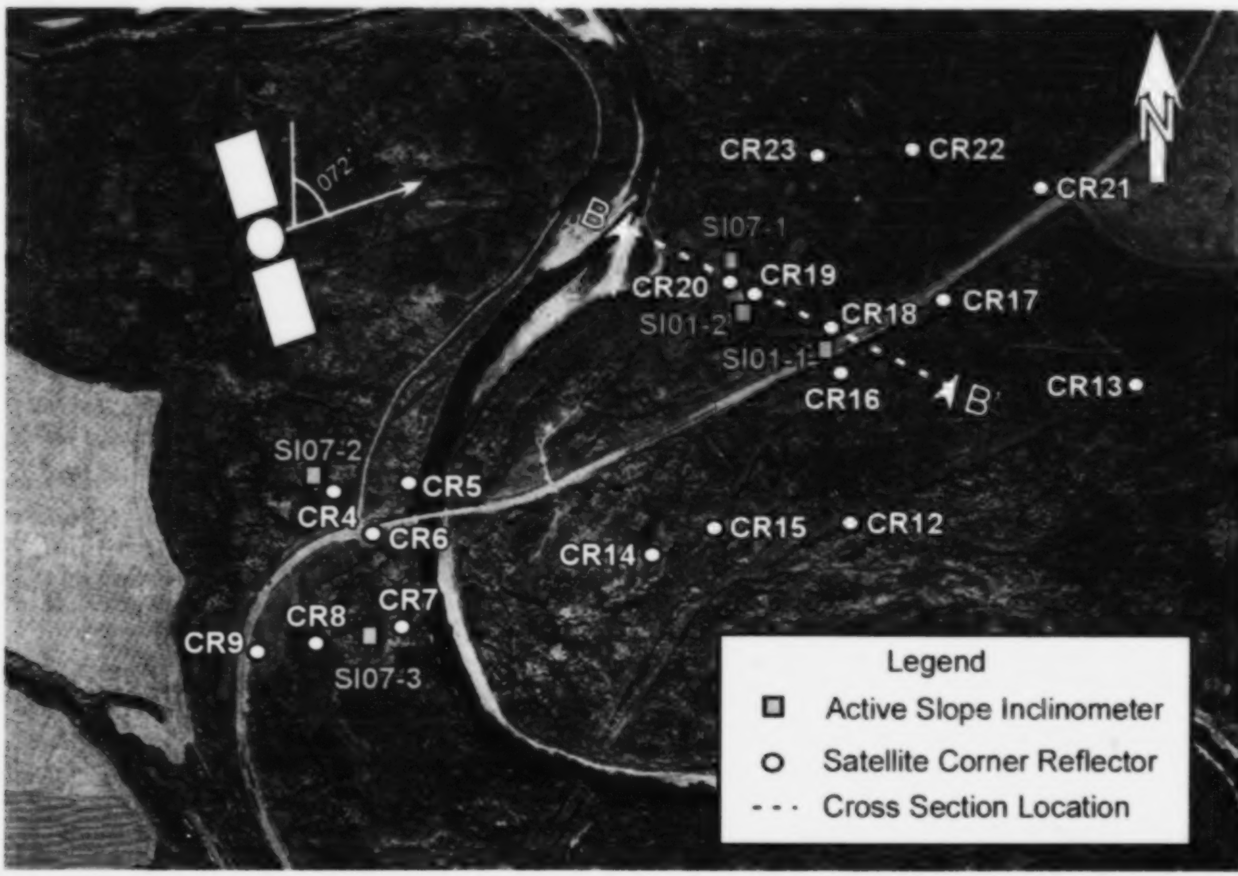
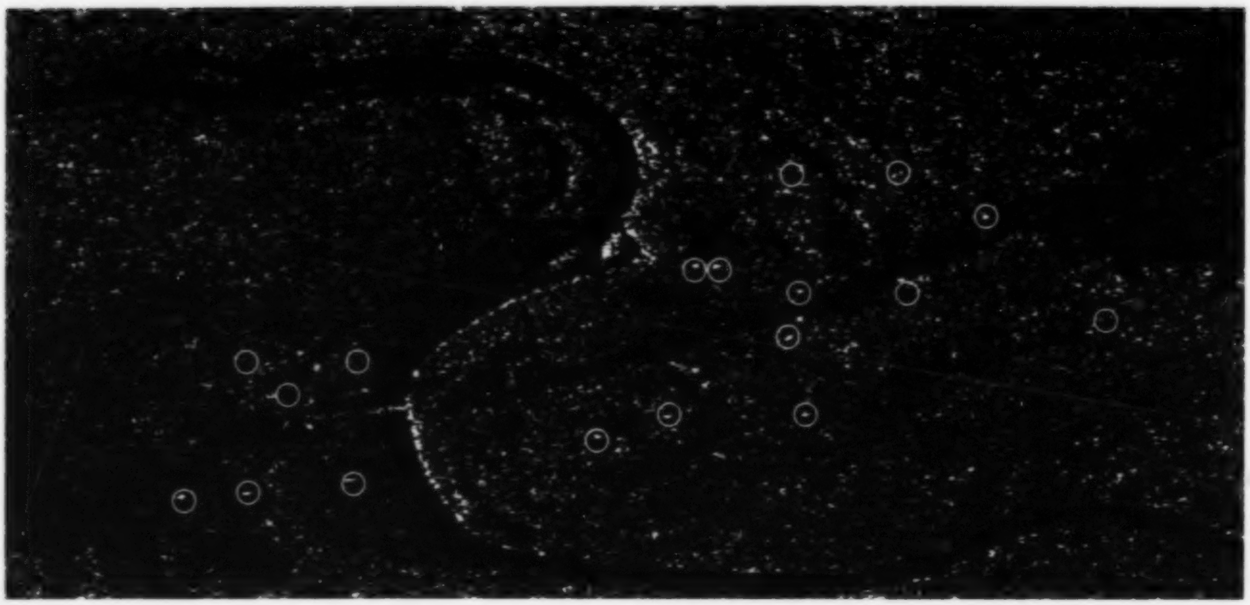


Clearing of site and reflector installation (left) and close-up of a corner reflector installed at the Little Smoky site (right).



Layout of the corner reflector array in relation to recently installed instrumentation and profile locations.

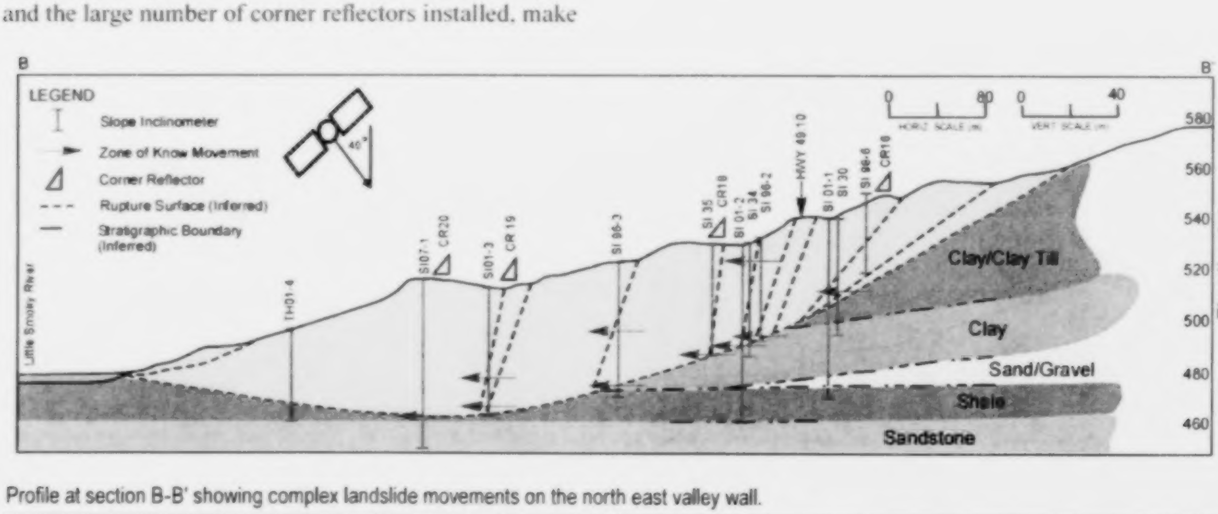


Radarsat-1 InSAR image showing the location of the corner reflectors (yellow spots) in relation to the surroundings. Higher data quality is indicated by higher reflectance.

On the northeast side of the valley, where the slope movements are toward the satellite, the complex rotational style of movement creates challenges in interpreting the results. As shown on Section B-B', the landslide on the northeast valley wall comprises a large number of blocks stacked upon one another like dominoes and move down and out in a rotational manner. As the top portions of these blocks move downward, the movements seen on the reflectors are across (perpendicular) to the radar pulses, and therefore, only a small component of the actual movements are measured using the satellite.

The complexity of the movements at the Little Smoky, and the large number of corner reflectors installed, make this application unique and the results are garnering significant, international interest. Data acquisition continues on the site, along with monthly readings of the conventional instruments by Alberta Transportation and their consultants. Final results are expected in fall 2008.

Based on the early results of this study and the other two sites, the Canadian Space Agency has agreed to fund data acquisition to continue these studies and start new studies in the coming year to characterize ground movement. These will continue to be showcases for Canadian innovation in the use of space technologies for ground hazard risk management. ❖



Profile at section B-B' showing complex landslide movements on the north east valley wall.

Recently Released Publications

Digital Datasets

DIG 2008-0350 Groundwater Chemistry Database — Cold Lake, Alberta Area.

Geo-Notes

GEO 2008-01 Preliminary Hydrogeochemical Investigation of Alberta's Groundwater Database to Locate Areas with Diamond Potential. 37.5 MB PDF. $20.00.

GEO 2008-02 Preliminary Stratigraphic Framework for Selected Kimberlites in the Buffalo Head Hills Region, North-Central Alberta. 33.5 MB PDF. $20.00.

Earth Sciences Reports

ESR 2008-01 A Study of Peridotitic Garnet Xenocryst Compositions from Selected Ultramafic Bodies in the Northern Alberta Kimberlite Province: Implications for Mantle Stratigraphy and Garnet Classification. 3.73 MB PDF. $20.00.

Information Series

INF 136 Digital Mapping and 3D Visualization/ Modelling of Subsurface Geology Using ArcGIS 9.2 and Well Log Data. 1.59 MB PDF. $20.00

Maps

Map 418 Surficial Geology of the McLennan Area (NTS 83N/NE). 4.97 MB PDF. $20.00.

Map 419 Surficial Geology of the Slavey Creek Area Area (NTS 84N/SW). 6.8 MB PDF. $20.00.

Map 421 Surficial Geology of the High Prairie Area (NTS 83N/SE). 5.8 MB PDF. $20.00.

Open File Reports

OFR 2008-02 Surficial Geology of the McLennan Area (NTS 83N/NE), Alberta: Report to Complement Surficial Geology Map 418. 1.46 MB PDF. $20.00.

OFR 2008-01 Turtle Mountain Field Laboratory: 2006 Data and Activity Summary. 21.2 MB PDF. $20.00.

Special Reports

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SPE 091 Subsurface Characterization of Acid-Gas Injection Operations in the Provost Area. 15.4 MB PDF. $20.00.

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SPE 097 Geochemical, Mineralogical and Kimberlite Indicator Mineral Electron Microprobe Data from Silts, Heavy Mineral Concentrates and Waters from National Geochemical Reconnaissance Stream Sediment and Water Surveys in the Northeastern and Southern Clear Hills, Alberta (NTS 84E/01 and 84E/02 and Parts of 84D/10 and 84D/11). 10 MB PDF. $20.00.

(This report is also released as Geological Survey of Canada Open File 5807).

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Geothermal Energy — New Opportunities for Alberta

Geothermal energy, the heat contained below the Earth's surface, can be found everywhere: on land, below the oceans and even in the polar regions.

Modern attempts to use geothermal energy go back more than a hundred years, but its development has been uneven due to slow technological breakthroughs and historically low oil and gas prices. Recent high energy prices and concerns over global warming have stimulated renewed interest and support for what is potentially a very large and renewable energy resource.

Geothermal energy is categorized by temperature (Table 1, next page) and use (heat or electricity). Indirect heating by heat pumps (also called geoexchange) is a relatively new technology, as is binary cycle production of electricity (Figure 1). Binary-cycle electrical generating plants pass moderately hot geothermal water by a secondary fluid with a much lower boiling point than water. This causes the secondary fluid to flash to vapor, which then drives the turbines.

The temperature level generally increases with depth, and the rate of increase is called the geothermal gradient. The gradient varies because of different lithological characteristics and groundwater flow. In Alberta, a typical geothermal gradient is 30°C for each one-kilometre increase in depth. About 90°C can be expected at a depth of three kilometres and temperatures approach 140°C in the deepest part of the basin.

Less is known about temperature in the Precambrian crystalline basement, and more information on heat flow and thermal conductivity is needed. This is particularly true if enhanced geothermal system projects (where bedrock permeability is created through hydraulic fracturing) are used for binary cycle power or where a hot spot is found and dry steam is at a workable depth. Technology and economics are improving, but extraction of geothermal energy deeper than 12 kilometres is currently not feasible. There are recent studies in Alberta looking at geothermal resources for oil sands production. The Alberta Energy Research Institute (AERI) along with Nexen Inc. and Shell Canada Ltd., have been looking at "Low Enthalpy Geothermal for Oil Sands" (LEGO) and major oil sands companies have formed a consortium called GeoPower in the Oil Sands, or GeoPOS, looking at higher temperature geothermal resources at greater depth. AERI and the Institute for Sustainable Energy, Environment and Economy (ISEEE) have also recently made available a study titled "Enhanced Geothermal Systems (EGS) Potential in the Alberta Basin."

The huge geothermal resources in deep saline aquifers that fall in the medium temperature range (40°C-140°C) remain largely untapped, but have a great potential as technology and energy economics change. In July 2006, the Chena geothermal power plant in Alaska came online with 74°C water from its geothermal wells, establishing a new lower-temperature threshold for binary power plants.

Interestingly, it is the low temperature (4°C–8°C) geothermal energy that's currently being developed in Alberta, mainly 100 metres from the surface. The use of ground-source heat pumps by commercial and residential users has expanded rapidly worldwide and most recently in Alberta. A heat pump is a machine (like a refrigerator or air conditioner) that uses a refrigerant to move heat from one place to another. A geothermal heat pump uses the ground (surficial material and/or bedrock) or groundwater as a thermal energy source to heat a building, or as a thermal energy sink to cool a building.

Shallow, ground-source geothermal energy provides

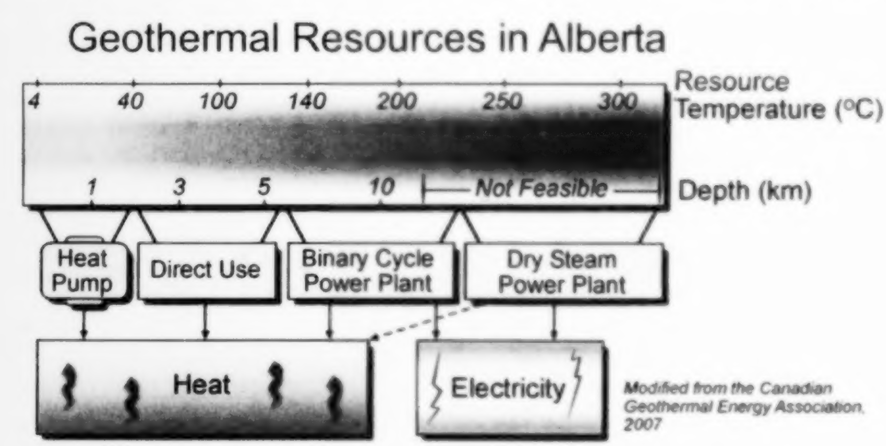

Figure 1. Generalized geothermal resource potential for Alberta showing the relationship between temperature, depth, technology and end-use.

Table 1. Categorization of geothermal energy by temperature and relative potential

Low Temperature (4°C–39°C)	• Growing industry in Alberta in response to increasing gas prices and environmental awareness • Possible conflicts with groundwater use • Potential thermal and chemical impacts on soil, bedrock and groundwater • Largely unregulated industry, lack of quality assurance of design and installation
Medium Temperature (40°C–140°C)	• High potential in Alberta due to existing infrastructure (oil and gas wells) • Immediately available; electricity produced at oil production sites in the U.S. • Equivalent estimated energy resource of up to 5 trillion barrels of oil • Water quality and corrosion issues • Lack of specific policy and regulations
High Temperature (>140°C)	• Low-emission, renewable alternative to coal and gas-fired power plants • High energy potential predicted by 2006 MIT study • High investment costs due to low temperature gradients in Alberta requiring Enhanced Geothermal Systems (EGS) with deep basement wells (>5 km) • Lack of knowledge of temperature gradients and permeability in the basement • EGS is still in the research stage with pilot projects in Australia, Switzerland and France • Induced seismicity, pressure effects and sustainability of geothermal source

space heating and cooling for houses and farms, as well as public and commercial buildings. The number of users is small compared to those using natural gas, but the geothermal installations are growing at a fast pace with thousands of units being installed each year. The advantage of ground-source geothermal energy is that it displaces valuable natural gas, which can then be used for other purposes. As well, increased use of geothermal energy may help reduce overall greenhouse gas emissions.

Discussions with geothermal energy contractor associations and representatives from all levels of government indicate that geoscience information plays a significant role in selecting, designing and implementing ground-source geothermal energy systems. Furthermore, geoscience information is deemed critical in addressing land-use issues and potential environmental concerns (such as groundwater contamination) regarding the widespread adoption of this technology.

More specifically, the geoexchange industry benefits from geological information that facilitates the

- selection of viable geoexchange types and determining which option may be most favourable for a site;
- evaluation of geoexchange options to estimate costs or adjust configurations to improve construction; and
- prediction of thermal exchange properties for various geological materials.

Each of these three key areas can substantially affect the cost and efficiency of the geoexchange system. Furthermore, geoscience data can provide significant value to small systems used in most domestic installations. ❖

Part 2 of this article will be in the 2008 fall issue of Rock Chips.

Story Contact Information

The following AGS staff members may be contacted for further information on their articles or citations.

Satellite-Based Mapping of Landslide Movements on Little Smoky River	Corey Froese	(780) 427-2872
Geothermal Energy — New Opportunities for Alberta	Matt Grobe	(780) 427-2843

Staff may also be contacted via e-mail by entering the author's first name.last name@ercb.ca.

Comments and suggestions for Rock Chips may be sent to Maryanne Protz at maryanne.protz@ercb.ca.

Conferences Involving Alberta Geological Survey

GeoEdmonton '08

61st Canadian Geotechnical Conference and 9th Joint CGS/IAH-CNC Groundwater Conference
September 21 – 24, 2008
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Edmonton, Alberta

CSUG 2008

Unconventional Gas Conference
November 19 – 21, 2008
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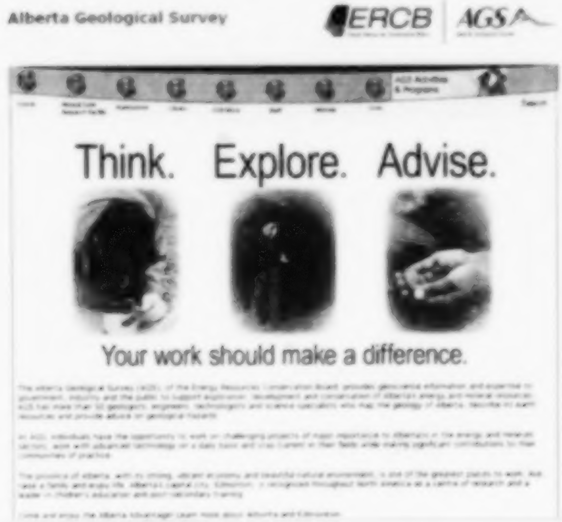

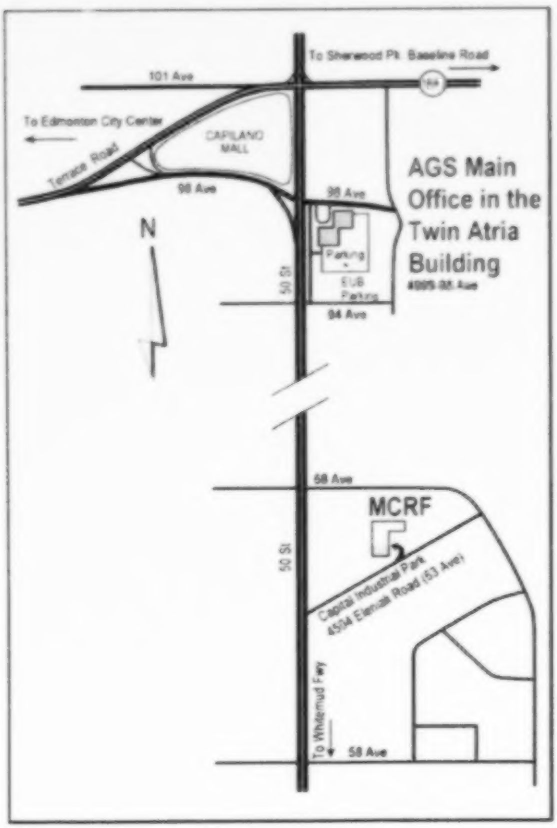

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4th Floor, Twin Atria Building
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